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The Whittier Narrows Earthquake of October 1, 1987 A Reconnaissance Report

By H. S. Lew

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U.S. DEPARTMENT OF COMMERCE, C. William Verity, *Acting Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

ABSTRACT

Within hours following the Whittier Narrows earthquake of October 1, 1987, a structural engineer from the Center for Building Technology, National Bureau of Standards surveyed the damage to buildings and other structures. The area investigated covers Los Angeles and other communities including Whittier, Alhambra, and Pasadena. This report consists of photographs, all of which were taken by the author. The photographs presented herein are intended to serve as (1) documentation of the damage resulting from the earthquake and (2) as a source document for further studies, research and recommendations.

Key words: Bridges; buildings; earthquake; highways; housing; seismic; structural engineering.

INTRODUCTION

At 7:42 a.m. (Pacific Daylight Time), on October 1, 1987, an earthquake with a magnitude of approximately 6.1 on the Richter scale occurred, with its epicenter located about 20 km east of downtown Los Angeles, California, at 34° 05′ N and 118° 07′ W. The earthquake resulted from a fault rupture along a northwest extension of the previously identified Whittier fault (see fig.1). The initial shock originated approximately 11 km below the earth's surface. Following the main shock, many aftershocks occurred including the ones that occurred on October 4, 1987 with a magnitude of 5.5 and on October 5, 1987 with a magnitude of 4.3.

Ground shaking in the vicinity of the epicenter ranged from 0.2g (gravity) to 0.45g in the horizontal direction and from 0.14g to 0.2g in the vertical direction. Maximum ground accelerations recorded at some of the stations near the epicenter are listed below. These stations are maintained by the California State Division of Mines and Geology (CDMG), which provided preliminary readings of their instruments. The solid circles in Figure 2 show the locations of these stations.

Location	Dist. From Epicenter	Vert.Acc. (g)	Horz.Acc. (g)
Fremont School Alhambra	7 km	0.20	0.40
S W Academy San Marino	8 km	0.14	0.20
Cal.State Univ. Los Angeles	9 km	0.14	0.39
Obregon Park Los Angeles	10 km	0.15	0.45
Sears Warehouse Los Angeles	14 km	0.09	0.18
Downey	17 km	0.17	0.20
116th School Los Angeles	22 km	0.11	0.40
Union Oil Co. Inglwood	25 km	0.08	0.28
Calif. Fed. Savings	26 km	0.10	0.22

The ground accelerograms recorded by CDMG stations at Obregon Park and Fremont School are shown in Figure 3. These traces show that the magnitude of accelerations in the east-west direction and the north-south direction were about the same, and that strong shaking lasted for about 5 seconds.

Compared to other major earthquakes, the Whittier Narrows earthquake was moderate. Listed below, for comparison, are some earthquakes of substantial magnitude.

Location	Magnitude	Date
Anchorage, Alaska	8.4	March 27, 1964
San Francisco, Calif.	8.2	April 18, 1906
Kern County, Calif.	7.7	July 21, 1952
Olympia, Washington	7.1	April 13, 1949
El Centro, Calif.	7.1	May 18, 1940
Coalinga, Calif.	6.7	May 2, 1983
San Fernando, Calif.	6.6	Feb 9, 1971
Imperial Valley, Calif.	6.5	Oct 15, 1979
Morgan Hill, Calif.	6.1	April 24, 1984
Whittier Narrows, Calif.	6.1	Oct 1, 1987

The most severe damage to building structures occurred in communities east of Los Angeles and near the epicenter. These communities include Whittier, Montebello, Monterey Park, Alhambra, Rosemead, San Gabriel, San Marino and Pasadena. No severe structural damage to high-rise structures in downtown Los Angeles was reported. However, some buildings sustained non-structural damage. Severe damage to one interchange structure (I-605/I-5) resulted in closing of I-605 for about a day. While six persons lost their lives as a result of the main shock, only one person died due to failure of a structural component.

This report consists of photographs taken by the author illustrating the type and intensity of damage. Most of these photographs were taken from the street, as entry into the damaged buildings was not allowed immediately following the main shock.

DAMAGE OBSERVATIONS

Unreinforced Masonry Buildings

There are many unreinforced masonry buildings in the communities shaken by the earthquake. The extent of damage to these buildings varied considerably, ranging from minor cracks in walls to partial collapse of a building. The most severe damage to unreinforced masonry buildings appeared to have occurred in the "Uptown Business District" in Whittier. Typical damage to unreinforced masonry buildings included cracks in the exterior walls, collapse of parapets and exterior walls, and collapse of roofs. Similar damage was also observed in the old downtown section of Alhambra and in the "Old Town" section of Pasadena. Several of the damaged buildings in Pasadena had been

posted by the building official as unsafe for occupancy prior to the earthquake. In general, severe damage was concentrated in a localized area of these communities. For example, in Whittier damage was concentrated in the uptown business zone and in the adjoining residential area. Photos 1 through 6 illustrate the types of damage observed in unreinforced masonry buildings.

Residential Buildings

Most residential buildings which sustained damage can be divided into three categories. The first category includes single-story houses which were built of clay tile and other masonry units. Typically, these houses sustained either severe cracking in walls or partial collapse of walls. The second category includes houses which were not fully anchored to the foundation wall. As a result, these houses sustained horizontal cracks along the top of the foundations. walls. In some extreme cases, houses were completely dislodged from their foundations. The third category includes residential structures described as "house-on-garage." Typically, these structures have dwelling units built on top of garages having large door openings. In general, most of the damaged residential structures were relatively old and had been constructed before the 1971 San Fernando earthquake. The San Fernando earthquake revealed many weaknesses in residential construction that led to revisions to building code requirements.

As in previous earthquakes, many chimneys collapsed. Damage to chimneys was observed in many areas including Whittier, Alhambra and Pasadena. In some cases, chimneys toppled and fell though roofs.

In general, wood frame houses did not sustain serious damage. In many cases, the exterior stucco cracked, particularly at the corners of window openings. When window openings existed at the corners of wood frame buildings, many window panes were broken due to large distortions of the window frames.

Masonry walls are commonly erected at the boundaries of adjoining properties. If these walls are not reinforced, they are highly susceptible to collapse when subjected to a moderate shaking. Many such unreinforced concrete block walls collapsed in Whittier.

Photos 7 through 17 depict types of damage sustained by residential structures and walls.

Reinforced Concrete Frame Structures

Most of the major buildings on the California State University, Los Angeles campus are reinforced concrete frame structures. The buildings were constructed during the mid- and late-sixties. For example, the 8-story administration building was constructed in 1969. The campus was subjected to maximum ground accelerations of 0.39g in the horizontal direction and 0.14g in the vertical direction. Three multi-story buildings and a garage building which were inspected showed signs of structural distress. These included cracks in concrete shear walls and columns, cracking in the flat slabs around columns, damage to concrete members due to pounding of two structurally separated

sections of a building, and connection failures of a precast concrete fascia panel. A student died when she was crushed when this panel fell from a parking structure. Photos 18 through 24 illustrate some of the structural damage seen on the campus.

Extensive damage occurred to a reinforced concrete structure in Whittier. A garage in Whittier Quad experienced a partial collapse of the upper level floor and severe cracking in the columns. The garage was constructed in 1964. Deep beams, which supported the floor slab, were seated on circular interior columns and rectangular perimeter columns. Because of the short length of the interior columns, they attracted large shear forces and experienced brittle shear failure. The exterior columns did not have adequate ties to resist large shear forces and some of them failed. These exterior columns appeared to have widely spaced #2 and #3 bar ties. Photos 25 to 32 show structural damage to the garage.

Glass Breakage

Many stores in the uptown Whittier shopping area occupy renovated one- or two-story unreinforced masonry structures. Typically, the front of these stores have large windows. The glass in many windows fractured into large pieces and fell on sidewalks. Fortunately, at 7:42 a.m. the shopping area was not crowded with people and no one was injured seriously. Photos 33, 34 and 35 show store fronts which lost glass panes.

Non-Structural Damage

During an earthquake, falling light fixtures, suspended ceilings and ceiling tiles pose serious hazards to the occupants. Current codes require that light fixtures and suspended ceilings be properly secured so that they will not fall during an earthquake. During the main shock, light fixtures and suspended ceilings fell in many buildings located within a 10-km radius of the epicenter, particularly the Whittier area. Photos 36 through 39 show loss of ceiling tiles and light fixtures.

Highway Bridges

Immediately after the main shock, highway bridges were inspected by the California Department of Transportation (Cal Tran). Very little damage was sustained by most of the bridges near the epicenter except at the interchange of I-605 and I-5, where the columns in the center bent were severly damaged. The damaged bent supported 2 spans of precast concrete I-girders for the I-605 Freeway which crosses over the I-5 Freeway. Restraining cables installed by Cal Tran after the San Fernando earthquake, kept the precast girders from being dislodged from the bentcap. The interchange was closed to traffic for 22 hours after the main shock. Temporary shoring was placed on both sides of the damaged bent to support the precast girders. Photos 40 through 45 show the damaged overpass and columns and the temporary support system.

OBSERVATIONS

1. Unreinforced masonry structures sustained major damage during the earthquake.

2. Walls with large window openings provided little in-plan stiffness; resulting large distortions caused breakage of glass.

3. Residential structures which were not anchored slid off their foundation walls and sustained severe damage.

4. Reinforced concrete columns which did not have adequate shear reinforcement experienced extensive diagonal cracking and crushing of the concrete core.

5. Inadequately braced light fixtures and suspended ceilings fell during the earthquake.

6. Wood frame single-family houses with stucco exteriors sustained little damage.

7. Restraining cables kept precast bridge girders from sliding off the bentcap.

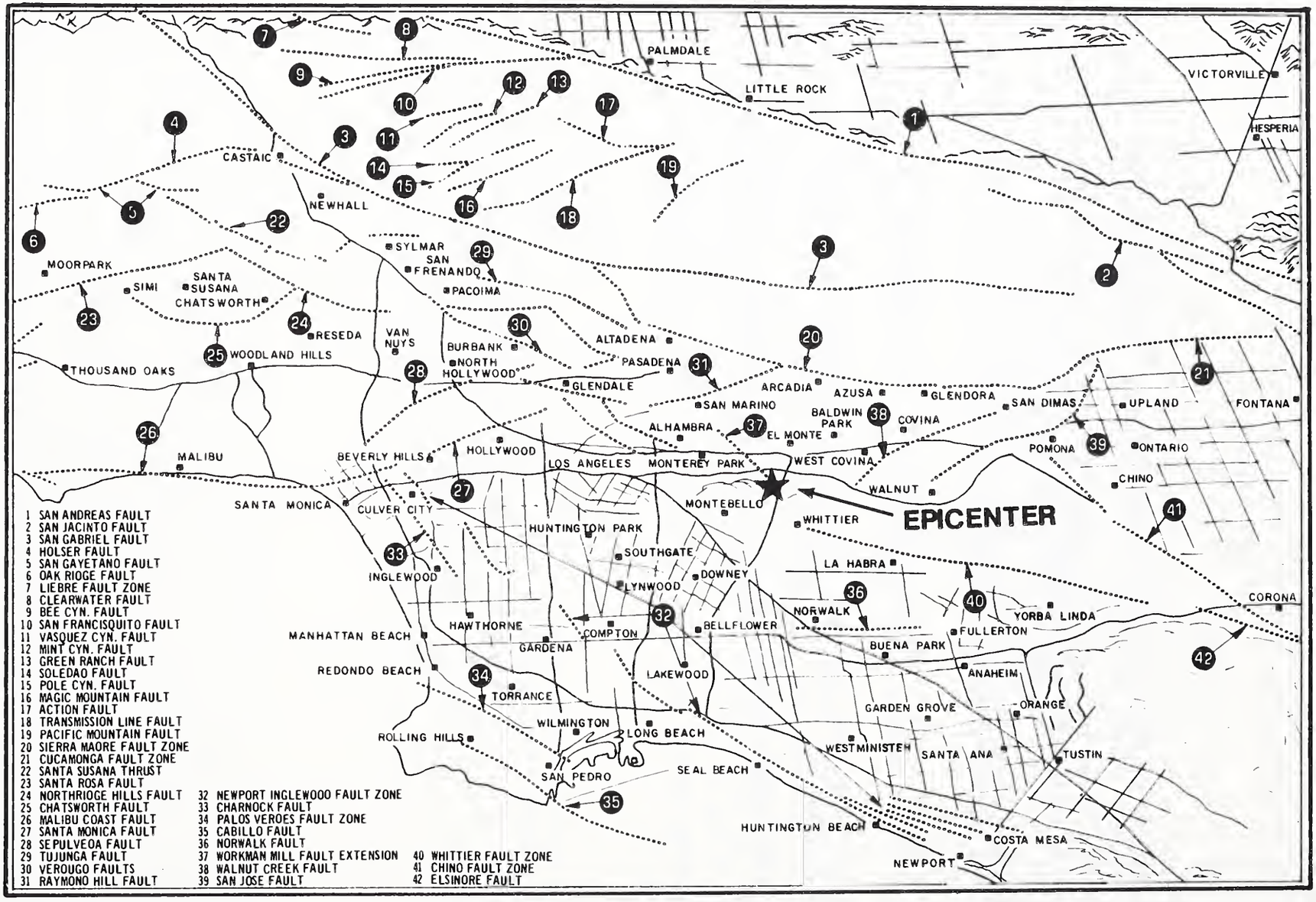

Figure 1 Location of known faults in the Los Angeles area

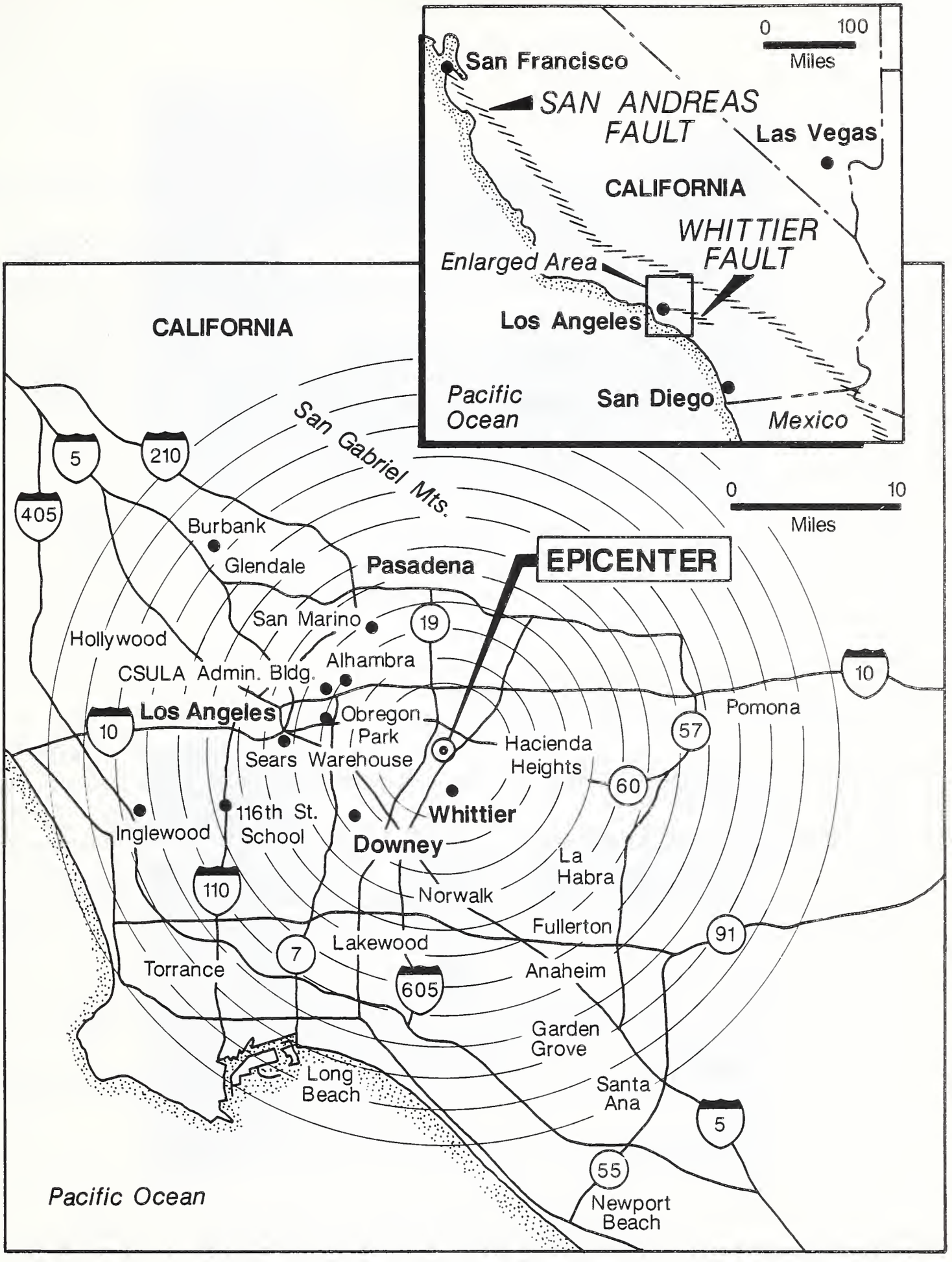

Figure 2 Location of strong-motion seismographs in the Los Angeles area (California State Division of Mines and Geology)

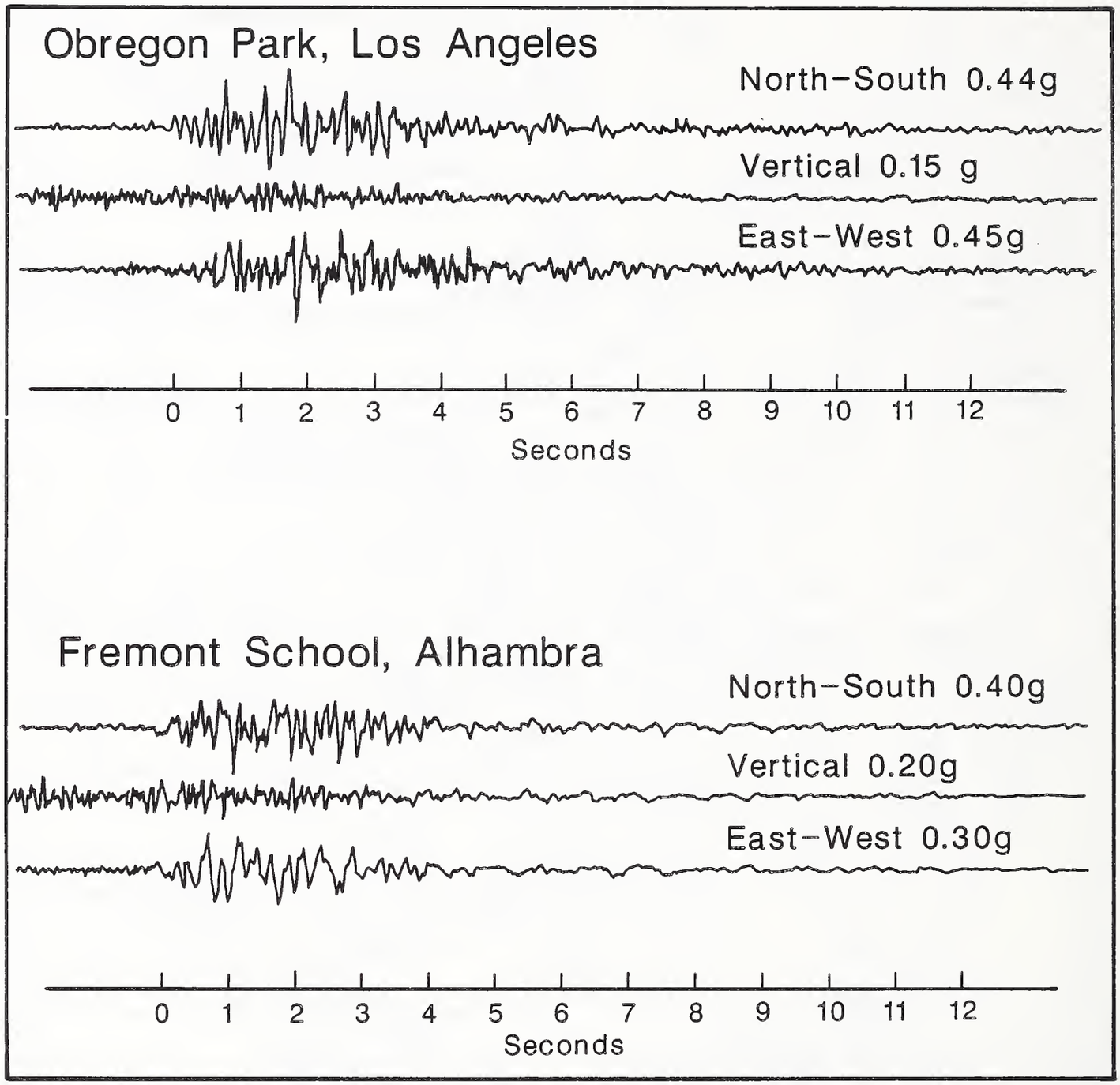

Figure 3 Seismograph records at Obregon Park and Fremont School

Photo 1 Total collapse of brick masonry wall of 2-story unreinforced masonry building in Uptown, Whittier.

Photo 2 Collapsed unreinforced brick parapet and wall of a building in Uptown, Whittier. Falling bricks crushed cars parked adjacent to the building.

Photo 3 Typical collapse of unreinforced brick wall, Whittier.

Photo 4 Partially collapsed and severely cracked unreinforced brick wall, Whittier.

Photo 5 Wood trusses fell from a damaged masonry wall resulting in a partial collapse of the roof of a store, Whittier.

Photo 6 Masonry parapet of a three-story unreinforced masonry building fell, causing the collapse of an adjacent building, Pasadena.

Photo 7 Many houses with unreinforced hollow clay tile walls sustained severe damage. This house at the corner of Greenleaf Avenue and Beverly Blvd. in Whittier lost the front wall.

Photo 8 Large pieces of clay tile fell on the front yard of the house shown in Photo 7.

Photo 9 This house on Greenleaf Avenue lost part of the entrance and sustained severe cracks in the walls of unreinforced hollow clay tile.

Photo 10 Close-up view of the partially-collapsed front entrance to the house in Photo 9. Exterior walls were unreinforced clay tile and stucco.

Photo 11 A wood-frame house on Beverly Blvd., Whittier, was damaged severely when it slid off its foundation wall.

Photo 12

The house in Photo 11 dropped vertically about one ft. and moved laterally about one and a half ft.

Photo 13 A wood-frame house adjacent to the house in Photo 11 on Beverly Blvd., Whittier, also sustained severe damage when the earthquake dislodged the house from its foundation wall.

Photo 14 Close-up view of the house in Photo 13.

Photo 15 Damaged two-story wood frame apartment building in Whittier. Large garage door openings reduced the stiffness of the wall in the plane of the garage doors and reduced the resistance to lateral loads.

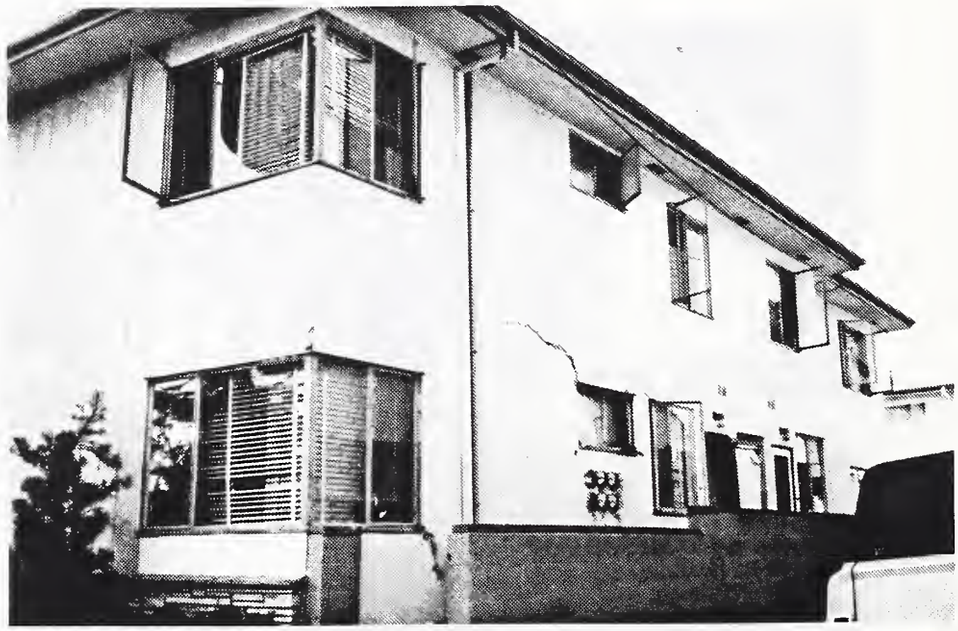

Photo 16 Large cracks developed at the corners of window openings. Note broken window panes at the corner of the building, Whittier.

Photo 17

Collapsed unreinforced concrete block wall in the residential section of Whittier.

Photo 18 The library building complex on the campus of the California State University in Los Angeles. The two buildings are connected by a structurally-separated walkway structure.

Photo 19

Glass panels at both ends of the walkway structure were broken due to an inadequate gap in the connection joint.

Photo 20

Cracks developed in some of the first-story columns of the walkway structure.

Photo 21

A class room building on the California State University campus. The exterior concrete frame for the precast concrete sun screen was damaged due to pounding of two structurally separated sections of the building.

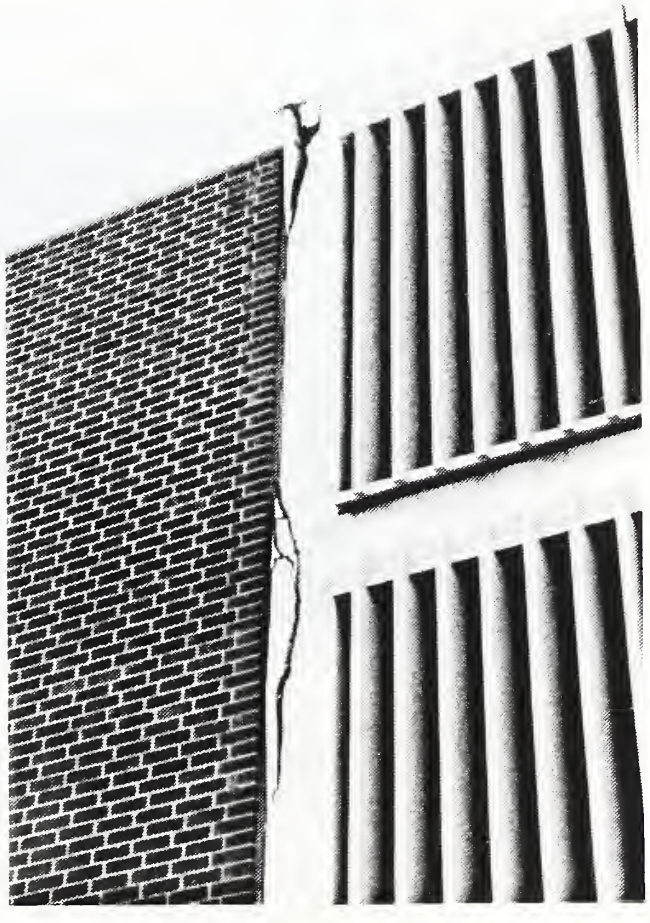

Photo 22

Close-up view of the damaged concrete frame.

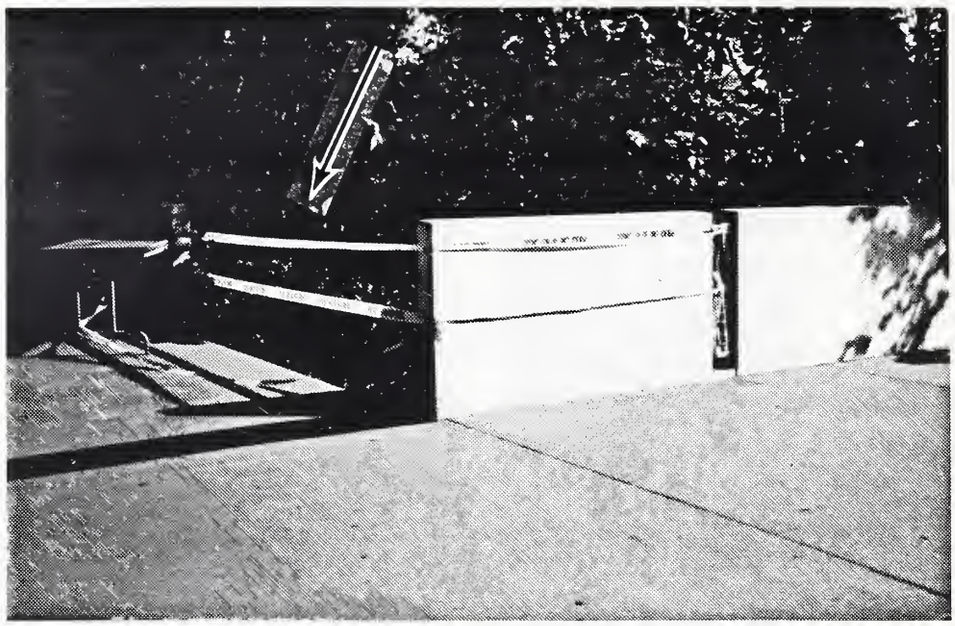

Photo 23 A precast concrete fascia unit fell when anchors held it to the concrete frame failed.

Photo 24 A precast concrete fascia unit fell two stories and fatally injured a passer by. This was the only fatality of the earthquake due to a structural failure.

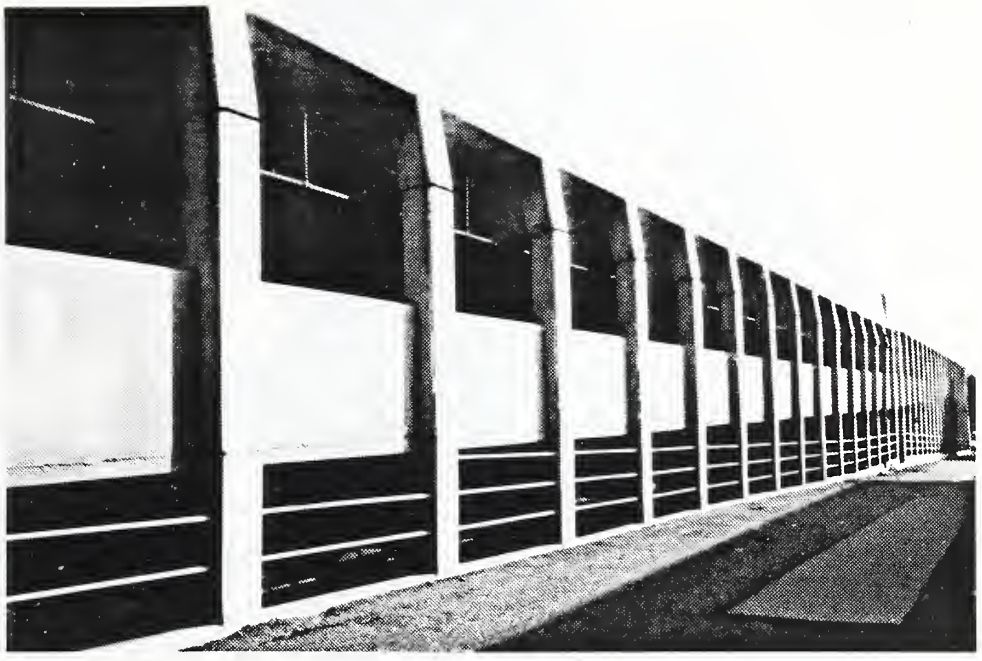

Photo 25 A damaged reinforced concrete parking garage at the Whittier Quad shopping center. Deep beams at the columns slant toward the inside of the structure due to the loss of support at the other side.

Photo 26 Extensive damage to relatively short columns and the ends of deep beams.

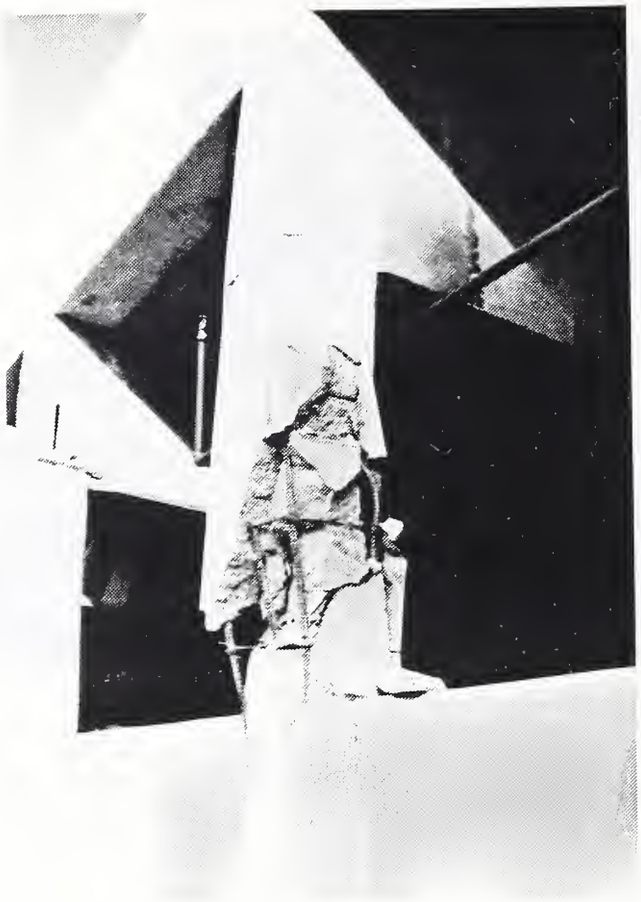

Photo 27

Typical shear failure of columns. Note #2 bars with large vertical spacing were used for ties.

Photo 28

Damage to a beam-column connection. Note that cardboard used to protect vertical column reinforcement during the construction stage was not removed when concrete was placed. This resulted in no bond between reinforcing bars and concrete.

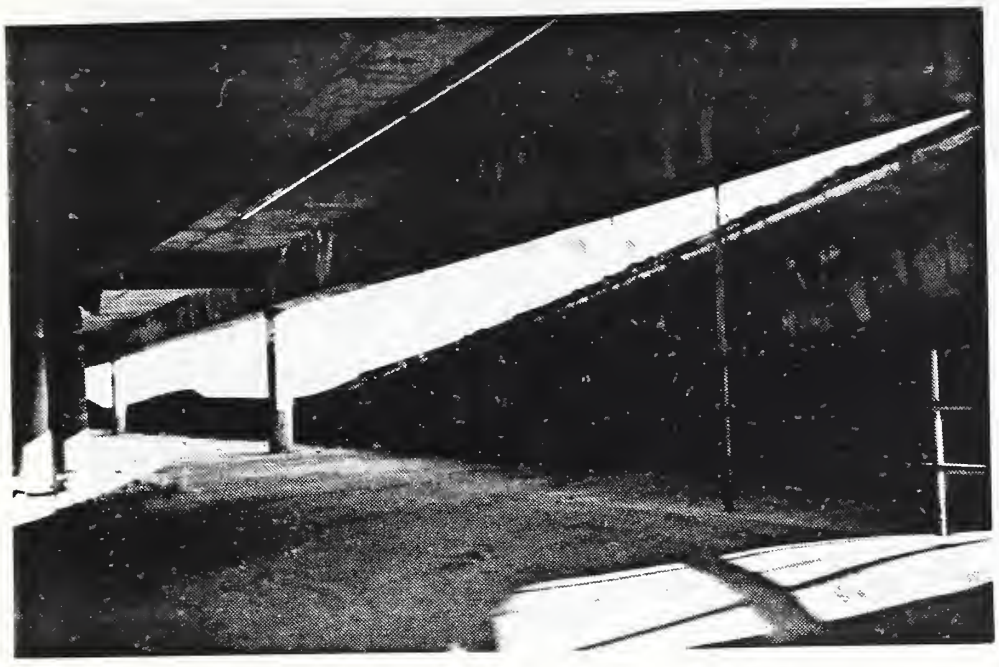

Photo 29 A collapsed upper level portion of the parking garage.

Photo 30

Damage to a concrete column between the ground level and the lower level. Note that no ties are around the vertical bar.

Photo 31 Non-ductile failure of a concrete column in the garage structure.

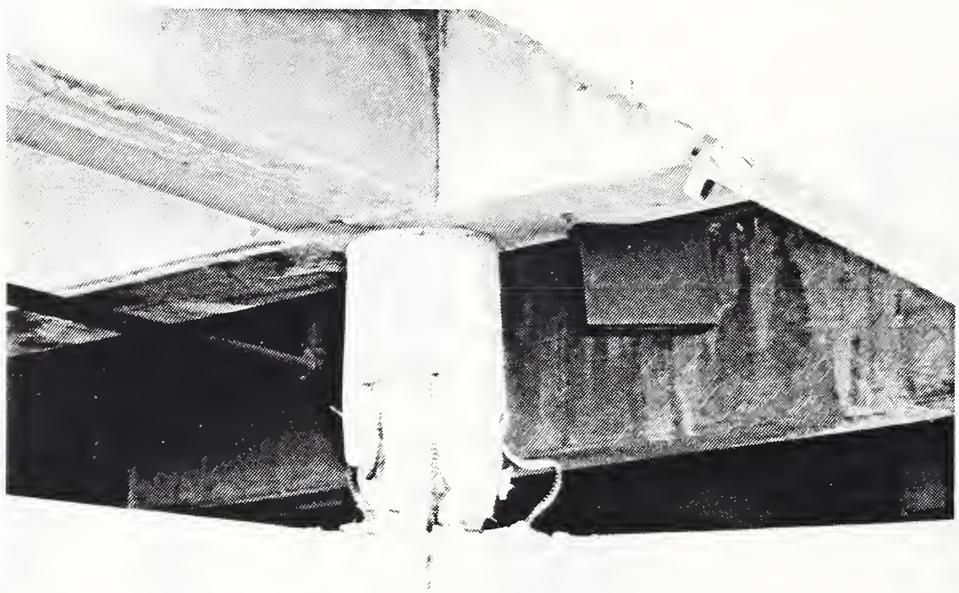

Photo 32 Non-ductile failure of a short column. Note fractured #2 tie and buckled vertical bars.

Photo 33 Distortion of the building caused damage to windows at the corner of the building in the Uptown Whittier shopping section.

Photo 34 Damage glass in a store in the Uptown Whittier shopping section.

Photo 35 This remodeled masonry building experienced considerable damage to windows. Because large pieces of brocken glass were strewn on the sidewalk, the building was cordoned off.

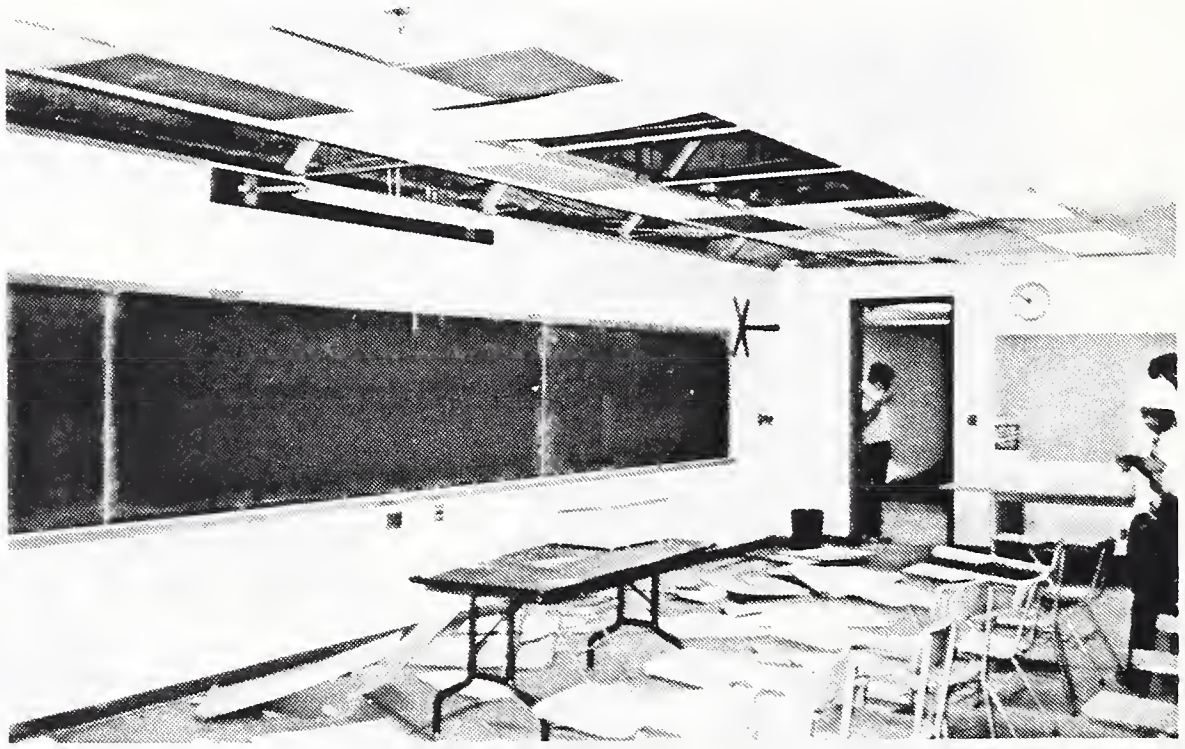

Photo 36 Fallen ceiling tiles in a classroom at the California State University at Los Angeles.

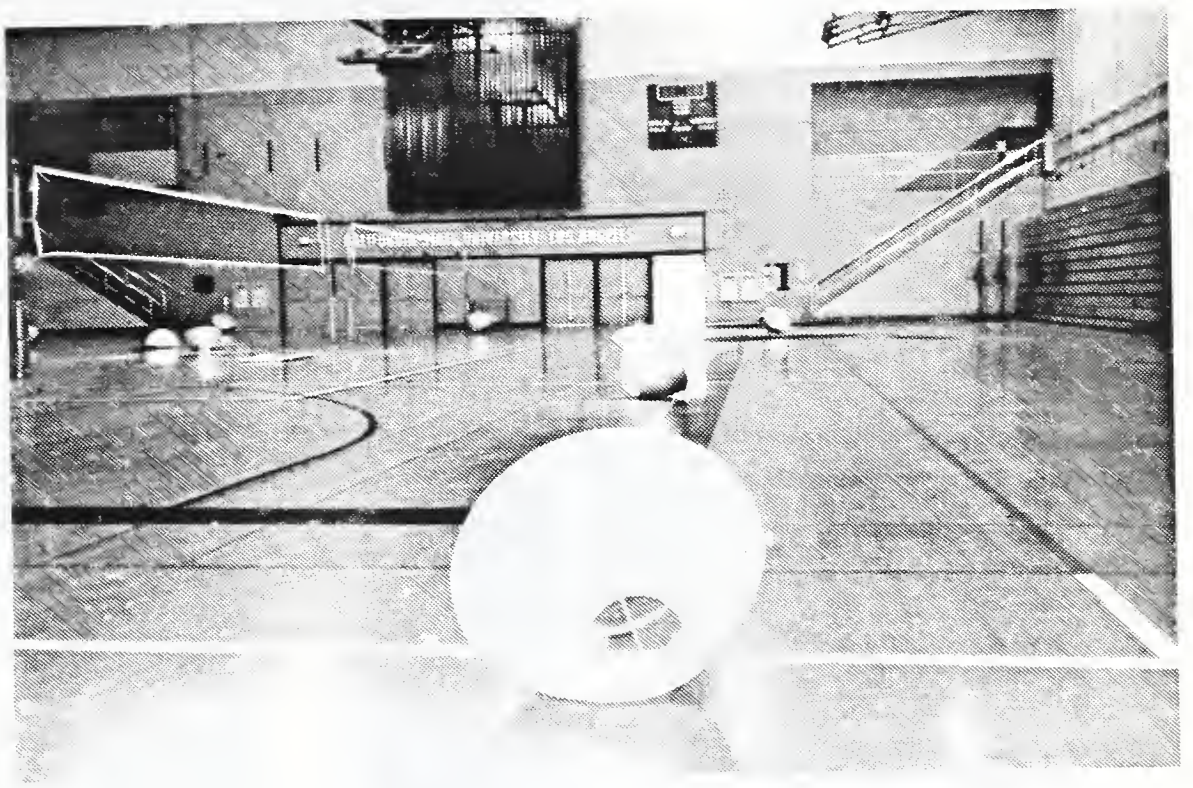

Photo 37 Fallen large light fixtures in the gymnasium at the California State University at Los Angeles.

Photo 38 This school building experienced minor structural damage. Note no glass was broken at the corner of the building.

Photo 39

Acoustic ceiling tile fell in corridors and stair wells at Rosemead High School.

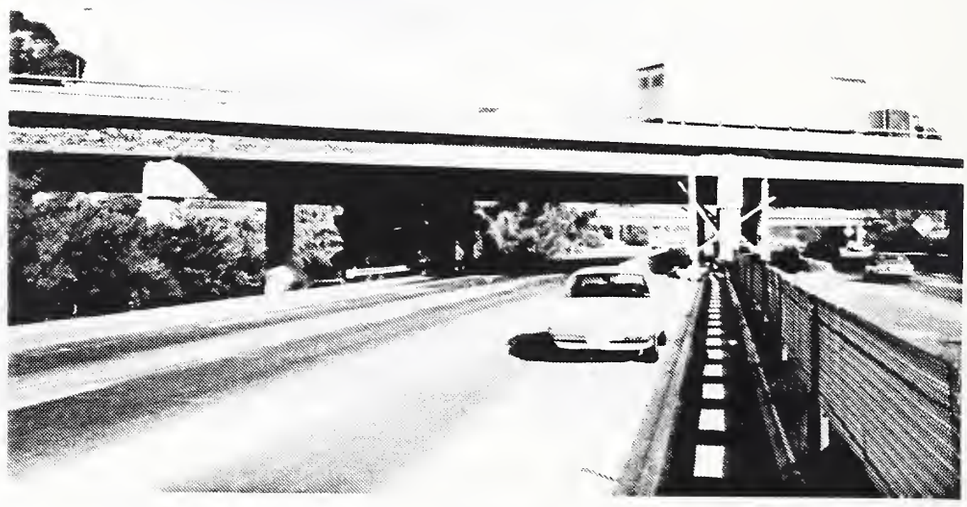

Photo 40 Interstate I-605/I-5 interchange. Temporary shores have been installed at the center bent which supports the I-605 overcrossing. The bent has five concrete columns.

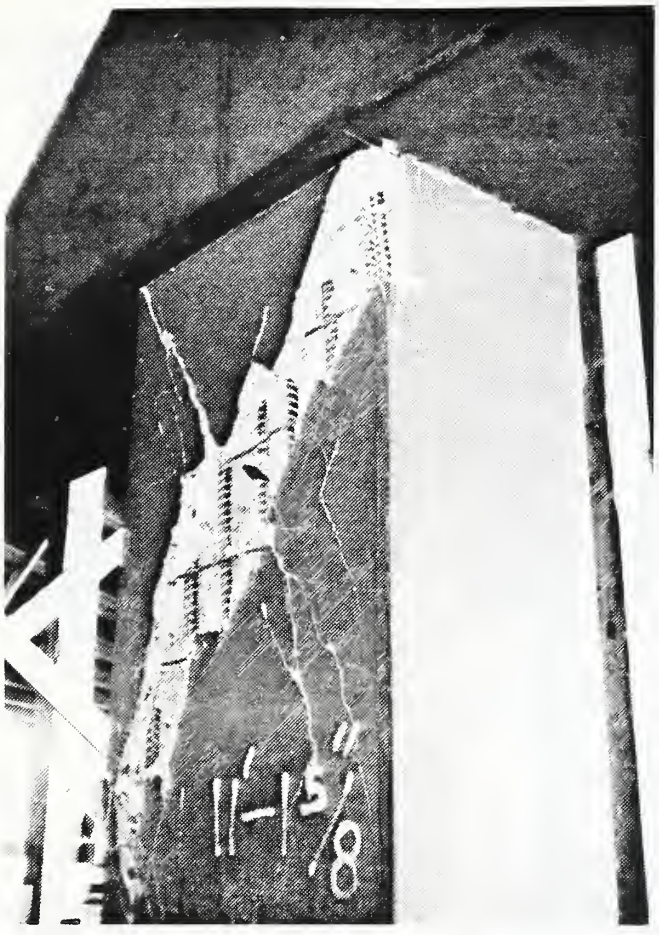

Photo 41

Close-up view of damaged column in the center bent.

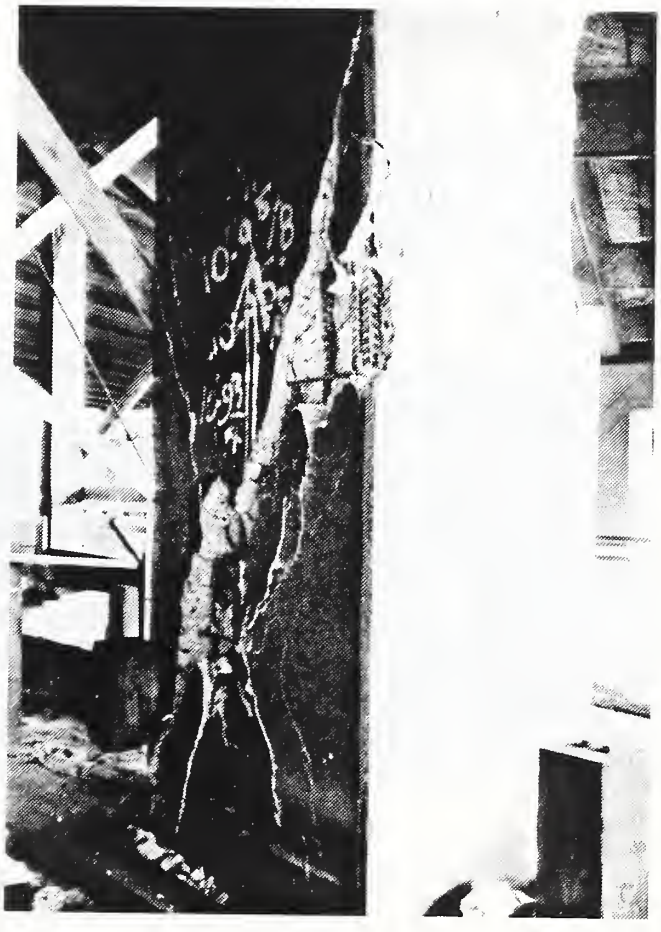

Photo 42

Close-up view of damaged column in the center bent.

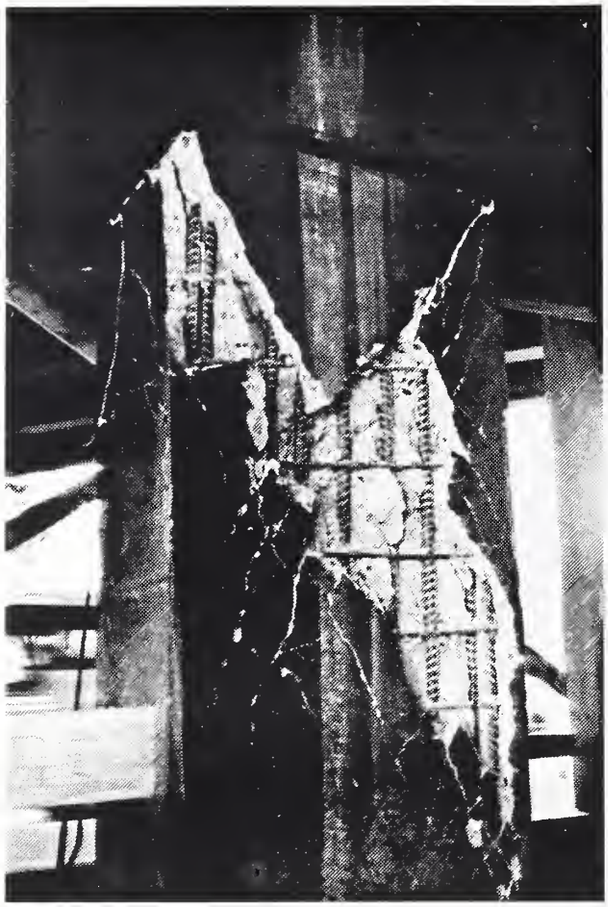

Photo 43

Close-up view of damaged column in the center bent. Note the cracked concrete core is confined by the ties.

Photo 44 Shoring scheme used to temporaryly support precast concrete girders.

Photo 45

Method used to support individual precast concrete girders.

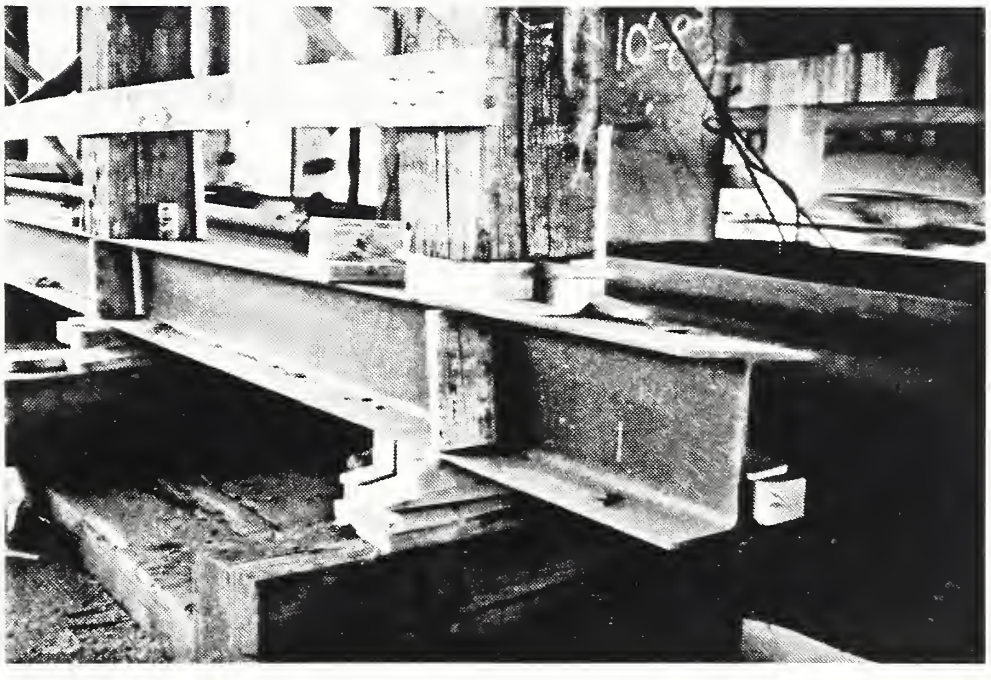

Photo 46 Support detail for individual shores.

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

Within hours following the Whittier Narrows earthquake of October 1, 1987, a structural engineer from the Center for Building Technology, National Bureau of Standards surveyed the damage to buildings and other structures. The area investigated covers Los Angeles and other communities including Whittier, Alhambra, and Pasadena. This report consists of photographs, all of which were taken by the NBS team. The photographs presented herein are intended to serve as (1) documentation of the damage resulting from the earthquake and (2) as a source document for further studies, research and recommendations.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

bridges; buildings; earthquake; highways; housing; seismic; structural engineering

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